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First record of *Zoanthus gigantus* Reimer & Tsukahara, 2006 (Anthozoa, Hexacorallia) from Indian waters, South Asia

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Abstract
Zoanthus gigantus, family Zoanthidae, is reported for the first time from south Asia. The earlier distribution of the species has been known only from Japan, China, and Taiwan waters. Colonies of *Z. gigantus* were noticed along Saurashtra coast, Gujarat, during a field survey, in frame of monitoring Zoantharian diversity along Indian coast. Species was identified using morphological and histological examination. The occurrence of *Z. gigantus* from this additional biogeographic region highlights the distribution range extension of the species.

Keywords
Cnidaria; Zoantharia; new record; Saurashtra coast; Gujarat; climate change.

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Introduction

In coral reef ecosystem, scleractinian corals have been extensively studied for their role as ecological bio-builders and as habitat for diverse invertebrate and fish communities (Krieger et al. 2002, Miller et al. 2009). However, taxonomic studies on other cnidarians that are found along with scleractinians and octocorals are few. One such taxonomically neglected group is order Zoantharia that makes up a considerable component of shallow water reefs around the world (Karlson 1980, Karlson 1983, Oigman-Pszcol et al. 2004, Irei et al. 2011) but has received little attention. This could be attributed to a lack of diagnostic characteristics, intraspecific morphological variations, and a high level of morphoplasticity shown by the group (Burnett et al., 1997, Ryland and Lancaster 2003, Reimeret al. 2004, Ong et al. 2013). Species of the order Zoantharia have a cosmopolitan distribution and are found from the intertidal to zones deeper than 5 m (Fosså and Nilsen 1998, Reimer et al. 2007, 2013, Reimer 2014). Zoantharians are usually colonial organisms and are characterized by 2 rows of tentacles and a single siphonoglyph, and the individual polyps are connected by a coenenchyme or common tissue like hard corals (Hertwig 1882, Haddon 1898). Most zoantharian often incorporate sand or detritus within their mesoglea or ectoderm, which helps them to provide strength and structure, except for the family Zoanthidae (Bourne 1990, Low et al. 2016), where no encrustation is seen. Traditionally the order Zoantharia has been divided into 3 suborders:

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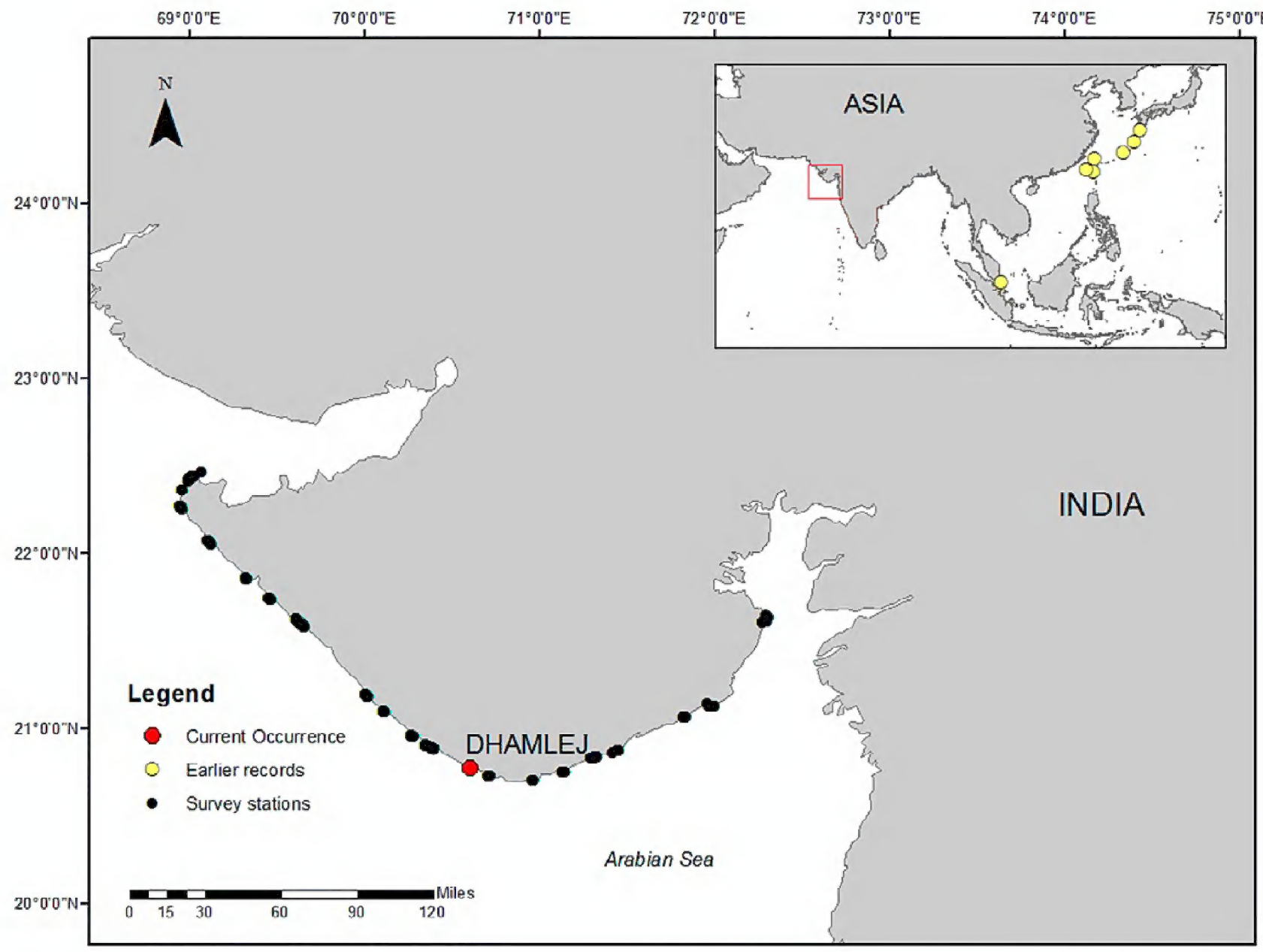

Figure 1. Geographic distribution map of *Zoanthus gigantus* Reimer &Tsukahara, 2006.

Macrocneminae and Brachycneminae (based on the fifth pair of mesenteria) and a group of incerta sedis. The suborder Macrocneminae is characterized by complete pair of fifth mesenteries from dorsal directive, while in the suborder Brachycneminae the fifth pair of mesenteriesis incomplete (Haddon and Schackelton 1891, Sinnigeret al. 2009, Reimer et al. 2011).

In India, zoantharians are mainly studied for their biochemical properties. Zoanthamine was first isolated from zoantharians along the coast of Vishkapatanam by Rao et al. (1984). Later, a novel sulfated sphingolipid (Hariamide) and 2-deoxyecdysterone (a novel oxytoxic agent) were extracted by Babu et al. (1997) and Parameswaran et al. (2001) from *Zoanthus* sp.Green Fluorescent Proteins (GFP) were extracted from *Z. sansibaricus* by Mythili and Gophane 2013. Studies describing the occurrence of zoantharian along the coast of the Indian subcontinent were carried out by Hornell (1910), Bhattiji (2010), Kaladhran et al. (2011), Pandya et al. (2013) and Trivedi et al. (2014). Based on mt DNA COI sequences, the phylogentic relationship of zoantharians was studied by Joseph et al. (2014) who reported the occurrence of 6 species from the Kathiawar Peninsula. Kumari et al. (2015) studied the distribution pattern and community structure of 7 different species of zoantharians in 3different genera (*Isaurus*, *Palythoa*, and *Zoanthus*) along the Saurashtra coast. Kumari et al. also discussed the effects of abiotic factors and environmental variability on Zoantharia. However, taxonomic studies in India pertaining to zoantharian diversity are still in their initial stage and the exact numbers of species are unknown.

Our study records *Zoanthus gigantus* Reimer & Tsukahara, 2006 for the first time from along the coast of Gujarat, India and we describe the taxonomic characters, both morphological (tentacle count, oral disk color, and polyp diameter) and histological (internal anatomy). Accordingly, we report *Z. gigantus* in South Asia for the first time.

Methods

Belt transect surveys using spaced quadrant frames (50 × 50 cm^2) laid along a line (Hill et al. 2005) were conducted to study the diversity and abundance of zoantharians along the Saurashtra coast of Gujarat, India (Fig. 1). Our study was carried in the intertidal zone from Okha (22°46′ N, 069°70′E) to Bhavnagar (21°76′ N, 072°15′ E) from 2013 to 2015. Twenty stations were selected and belt transects surveys (20), each 4 km long, were made at intertidal regions, along the coastline of approximately 400 km (Fig.1). Colonies of *Z. gigantus* were noticed only at the small fishing village of Dhamlej (20°46′35″N, 070°36′05″ E). In situ photographs of the colonies for examining external morphological features were taken using a digital camera (Nikon Coolpix AW310). Morphometric measurements such as polyp diameter were taken to the nearest millimeter using a digital Vernier caliper. A small portion of the colonies were collected for histological examination. The collected polyps were washed immediately with

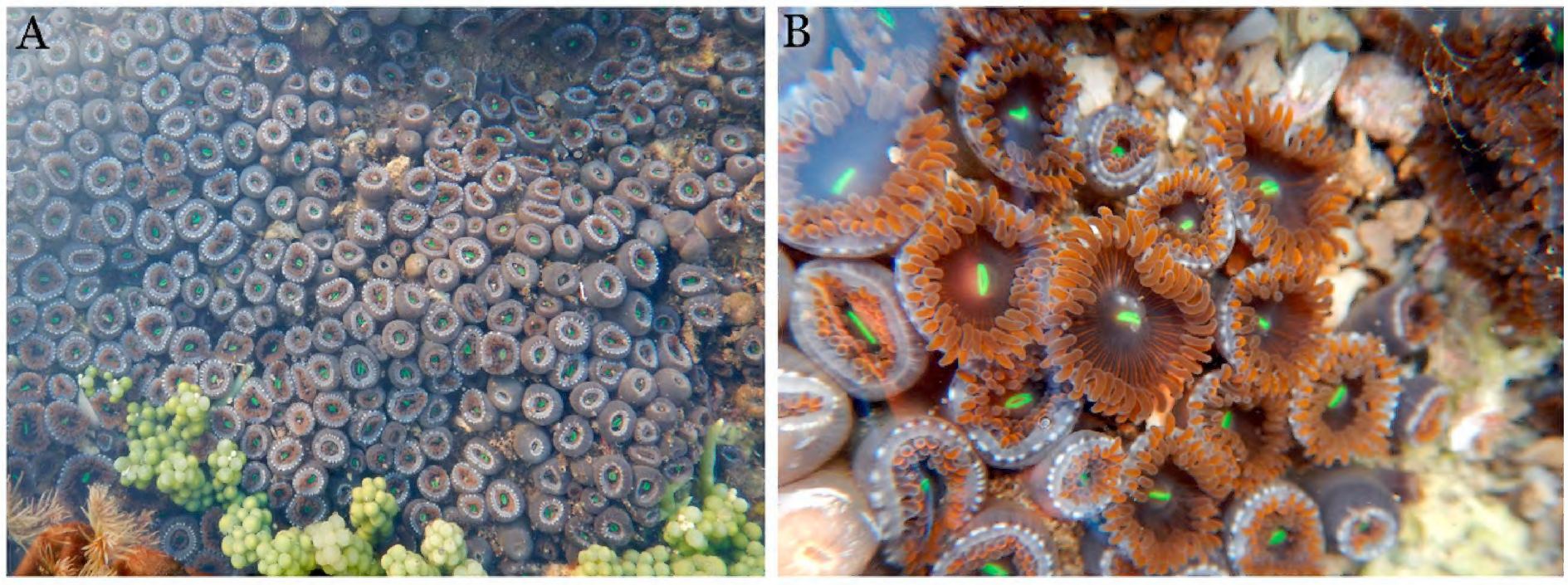

Figure 2. *Zoanthus gigantus* colony: **A.** Closed polyp. **B.** Open polyp.

saline and fixed in 4% a seawater-formaldehyde solution for 24 h and then transferred to 70% ethanol following the procedure described by Polak et al. (2011).The fixed tissues were later dehydrated in 80%, 90%, and100 % ethanol and embedded in histological-grade paraffin wax (Polak et al. 2011). Samples were serially cross-sectioned into 5µm thick sections along the length of the polyp with a Leica microtome (Leica, RM 2115) and stained using hematoxylin-eosin, followed by final mounting with DPX and observed under light microscope (Leica, DM RB fluorescent microscope). The histological sections were photographed using a Canon S70 camera. Reimer et al. (2006, 2007, 2011) were used for species identification. Identified specimens are deposited in the National Biodiversity Repository, CMFRI, Kochi(accession number CC.2.2.2, Marine biodiversity Museum CMFRI).

Results

Zoantharian diversity greatly varied among our stations and 8 species belonging to 3genera and 2 families were recorded. We found zoantharians to be more common in rocky intertidal areas as compared to areas where the substratum was primarily muddy or sandy, highlighting the need by zoantharians for a solid substratum. In Dhamlej zoantharians amounted to 55.3% of the benthic fauna, followed by Veraval(40.5%) and Adri (38.2%). All these stations showed the dominance of *Palythoa mutuki* followed by abundance of *Zoanthus sansibaricus*. However the colonies of *Z. gigantus* were found exclusively at Dhamlej and were completely absent from other stations. At Dhamlej this species contributed 3.36% of the total zoantharian cover.

Phylum Cnidaria
Class Anthozoa
Order Zoantharia Gray, 1832
Family Zoanthidae Rafinesque, 1815
Genus *Zoanthus* Lamarck,1801

Zoanthus gigantus Reimer &Tsukahara, 2006

Material examined. India, Gujarat, Dhamlej (20°46′35″ N, 070° 36’05″ E) Kumari S & Sreenath KR, 25.12.2015, National Biodiversity Repository, CC.2.2.2, Marine biodiversity Museum CMFRI, Kochi.

Colony morphology. Four colonies of *Z. gigantus* are recorded. These zoantharians are colonial, found at the lower eulittoral part of the intertidal area, where they form large colonies of approximately 500 polyps (Fig. 2). The external surface of each polyp is purplish brown with the characteristic white stripes (vertical markings) on the upper half of the head of the polyp; this is a character unique for this species (Figs 2, 4).

External anatomy. The body wall is not encrusted and the outer surface of each polyp feels smooth to the touch. The polyps are librae, that is, not crowded (Pax 1910), and extend from a poorly developed transparent coenenchyme. The oral disk is brown with a fluorescent green slit-like mouth opening. There are 2 rows of tentacles around the oral disk, with approximately 45–60 tentacles in each row. The tentacles are light to dark brown. The diameter of an open polyp varies from 6.5 mm to 9.7 mm. The polyp head is 2 times larger towards its oral opening than at its base, giving the polyp a swollen appearance when closed.

Internal anatomy. The mesenteries are in brachycnemic arrangements, with approximately 62 to 63 mesenteries in cross section. The mesogleal thickness is 663 µm in cross section (Fig.3).

Habitat. This species was attached with rocks in the lower eulittoral area where it formed large colonies approximately 500 polyps. The eulittoral shore was dominated by algae such as *Dictyota* sp., *Caulerpa* sp., *Sargassum* sp. and coralline algae.

Discussion

We report *Zoanthus gigantus* from the coast of Indian waters, the first time from South Asia. *Zoanthus gigantus* was first described from southern Japan by Reimer and Tsukuhara (2006). Other records are from Taiwan (Re-

Figure 3. Histoarchitecture of *Z. gigantus*. M: Mesentry, A: Actinophayrnx, MG: mesoglea, E: Ectoderm (magnification: ×40).

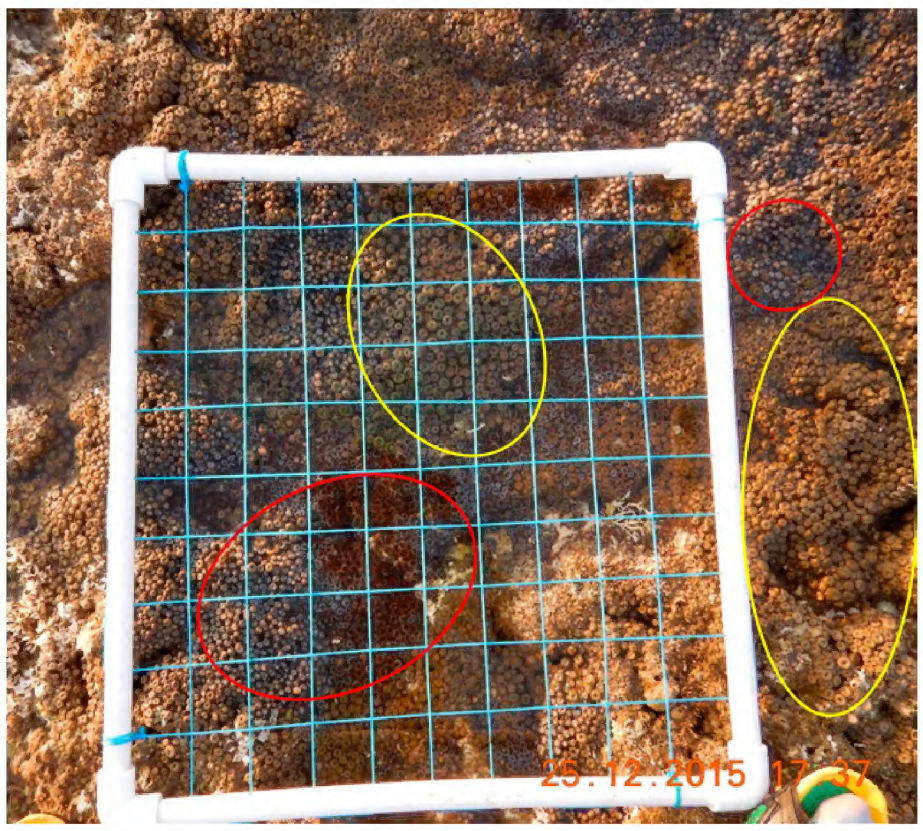

Figure 4. Co-inhabitation of *Z. gigantus* (depicted by red circle) and *Palythoa mutuki* (depicted by yellow circle) in transect.

imer et al. 2011, 2013), South China (Reimer 2015), and Dongsha Atoll (Reimer et al. 2016) (Fig.1). Our new record represents a considerable range extension of greater than 4500 km. The 4 colonies of *Z. gigantus* were found in habitats like those reported by Reimer et al. (2007). In the original description, the colony size was reported as small, fewer than 100 polyps (Reimer et al. (2011), unlike the large colonies reported here). Reimer et al. (2007) also reported variation in the color of individual polyps within a colony, but we observed only a single morphotype. We recorded colonies of *Z. gigantus* to be interspersed with colonies of *Palythoa mutuki*, which has not been observed before (Fig.4). An investigation into competition between colonies of these species is not within the scope of our study, but Rabelo et al. (2013) reported the cohabitation of *Zoanthus sociatus*(Ellis, 1768) and *Palythoa caribaeorum* (Duchassaing & Michelotti, 1860), suggesting that these species stop their growth when they come in contact with each other. Studies pertaining to competitive strategies between zoantharian and other organisms are important in understanding the dynamics of marine substrata and helpful in providing insights for management and conservational measures (Rabelo et al. 2013).

Although we sampled 20 sites from Okha to Bhavnagar for zoantharians, colonies of *Z. gigantus* were found only at Dhamlej, which is a densely populated village. There the intertidal area receives effluents from the fish landing harbor and domestic waste. Costa et al. (2008) and Huang et al. (2011) showed that zoantharian growth were favored in the habitats with nutrient enrichment and with increased concentration of organic matter. Although we did not sample for nutrient load in our study, the occurrence of yet another *Zoanthus* species

from hypertrophic, fecal polluted conditions suggests the resilience capacity of zoantharians, similar to the findings of Hernández-Delgado et al. (2008). Our study suggests a wide distribution for *Z. gigantus*, similar to other well-known species of *Palythoa* and *Zoanthus.*

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Authors' Contributions

SK and SKR were involved in the surveys, histological sectioning, staining and data analysis. ZPU, KV and GG are in the PhD advisory committee of SK, and they helped in conceiving, guiding, and interpreting the research. All authors read and approved the final manuscript.

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